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Effect of Soybean Varieties on the Yield and Quality of Tofu[1]

H. L. WANG, E. W. SWAIN, and W. F. KWOLEK, Northern Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, Peoria, IL 61604; and W. R. FEHR, Department of Agronomy, Iowa State University, Ames, IA 50011

ABSTRACT

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Tofu was made on a laboratory scale from five U.S. and five Japanese soybean varieties grown under the same environmental conditions. With one exception, all the tofu samples had a bland taste, fine texture, and creamy white color. Weber variety with a black hilum yielded tofu with a less attractive color. Differences observed among the 10 varieties were not attributable to the country of origin. Protein contents of soybeans and the resultant tofu (dry basis) were positively correlated. Soybean varieties with high protein content also produced tofu with a higher ratio of protein to oil than did varieties with smaller amounts of protein. The yield of tofu was positively correlated with protein recovery during processing, but not with the protein content of the beans. The hardness of tofu varied according to water content. Conditions in processing tofu greatly affect yield and quality. Varietal differences affected the composition and color of tofu. Varieties that have a light hilum and high protein content are preferred.

Tofu, a traditional oriental soybean food composed principally of protein and oil, is growing rapidly in popularity in the West. According to data from the Soyfoods Center (Shurtleff 1982), the number of nonoriental tofu producers in North America rose from 0 in 1975 to 167 in 1981. More than 11,000 tons of soybeans are used yearly in making tofu in the United States. Although the bulk of the soybean crop is still used for animal feeds and oil, the use of whole soybeans for human consumption is increasing steadily.

Tofu is made by precipitation of the proteins with a calcium or magnesium salt from a hot-water extract of whole soybeans. It is usually sold in the form of a wet cake with a creamy white color, smooth fine texture, and bland taste. Tofu is a highly hydrated, gelatinous product. Its water content can be varied to produce an array of tofu with different characteristics. The typical type in the Orient has an approximate composition of 85% water and 7.5% protein (Smith et al 1960, Table of Taiwan Food Composition 1971, Tsai et al 1981). This type of tofu has a soft, cheeselike texture but is firm enough to retain its shape after slicing. Tofu with water content as high as 87–90% (Standard Tables of Food Composition 1954, Tsai et al 1981) and a smooth, fragile texture is especially popular in Japan. In China, however, many types of firm, chewy tofu products with water content as low as 50–60% are popular. Tofu in U.S. markets contains 75–80% water. According to U.S. tofu producers, western consumers prefer tofu with a firm, chewy texture.

For centuries, the process of making tofu has been controlled by tradition and long experience; without the benefit of scientific knowledge, tofu "craftsmen" have skillfully carried on the process. In recent years, studies have been made on gel formation of proteins isolated from defatted soybean meal as well as from water extract of whole soybeans. Processing conditions, such as type and concentration of coagulants, temperature, mode of mixing, and pressure applied, that affect the quality and quantity of gel formation in tofu have been investigated (Lu et al 1980, Saio 1979, Tsai et al 1981, Wang and Hesseltine 1982, Watanabe et al 1960). Scientists have just begun to comprehend the centuries-old process of making tofu.

In addition to processing conditions, soybean variety has been reported to affect the yield and quality of tofu. Watanabe et al (1960) found that Japanese varieties were more desirable than U.S. varieties. But Smith et al (1960) reported that the most important differences between Japanese and U.S. soybeans, as viewed according to Japanese custom, were in texture and color of the tofu produced from them. Although yield and composition of tofu varied with soybean variety, the average yield from U.S. soybeans was the same as that from Japanese beans. However, the same authors cautioned that the differences in composition of beans probably reflected the effect of location as much as varietal differences. More recently, Skurray et al (1980) used 15 soybean varieties grown under the same agricultural conditions for making tofu and found that the amount of calcium used had a greater effect on the quality of tofu than did the variety of soybeans. Nevertheless, the problem persists in selecting the most suitable variety for making tofu.

In this study, soybean varieties originating in the United States

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and Japan and grown in the same location under the same environmental conditions were used to determine varietal variability in making tofu.

MATERIALS AND METHODS

Soybean Samples

Ten soybean varieties—five U.S. and five Japanese—were grown in two replications of a randomized complete block design at Ames, IA, in 1981. The five Japanese commercial varieties were sent to Iowa from Hokkaido, Japan, in 1980. Seed harvested from Iowa in 1980 was used to plant the same experiment in 1981 to eliminate any possible effect of seed source. The five U.S. varieties are commercially grown in Iowa. The Vinton variety was released specifically for food uses because of its high protein content and large seed. It is not recommended for planting, except when the farmer has a contract for sale of the beans to someone who sells soybeans to food processors, primarily tofu manufacturers. Yield of Vinton is lower than that of other available varieties.

Preparation of Tofu

Tofu was prepared by the method of Wang and Hesseltine (1982). Fifty grams of beans was washed and soaked in water at room temperature (20–22°C) for 16 hr to reach complete hydration. The soaked beans were drained, rinsed, and homogenized for 2 min in a Brinkman homogenizer with enough added water to give a water–dry beans (before soaking) ratio of 10:1 (weight basis). The slurry was brought to a boil and kept at boiling temperature for 15 min. The hot slurry was then filtered through four-layer cheesecloth to separate the milk from the pulp. Pressure was applied to the pulp with a press to harvest the maximum amount of milk. When the milk was cooled to about 70°C, 400 ml was forcefully poured into a calcium sulfate ($CaSO_4 \cdot 2H_2O$, Terra Alba) suspension to achieve a mixing action. The calcium sulfate suspension consists of 40 ml of water (10% volume of the milk) and 1.52 g of $CaSO_4 \cdot 2H_2O$, so that the final concentration of the salt in the milk is $0.02M$. After settling for 10 min, the curds were transferred to a cheesecloth-lined wooden box (7.5 × 7.5 × 7.5 cm) and pressed by placing weight (10 g/cm^2) on the top for 1 hr.

Texture Evaluation

The hardness of tofu was evaluated with an Instron Universal testing machine as previously described (Wang and Hesseltine 1982). Tofu samples cooled to room temperature were cut with a cork borer into a cylinder form having a 1-cm radius and a 2-cm height. The sample was compressed from 2 to 0.5 cm (75% deformation).

Analytical Methods

Moisture content was determined by drying samples to constant weight at 110°C. Protein and oil contents of beans were measured by near-infrared reflectance. Protein and oil contents of freeze-dried samples of soy milk and tofu were determined by micro-Kjeldahl analysis (AOAC 1970) and hexane extraction, respectively.

Tofu preparation was done twice for each sample from each replicate. Data were examined by analysis of variance. Variations attributable to origin and varieties within country of origin were estimated and tested for significance. Correlation coefficients were determined to measure the degree and significance of association among the various measurements.

RESULTS AND DISCUSSION

Tables I and II summarize the results statistically. Means are the average of four measurements, two for each replicate of the variety, except those for protein and oil contents of the beans, which represent the average of two measurements, one for each replicate.

Origin of Soybean Varieties

Using the same coagulation conditions, satisfactory tofu was made from all soybean samples. Significant variation among varieties was observed for protein and oil content of the beans, size of the beans (weight of 100 beans), amount of water absorbed at complete hydration, protein concentration of soy milk, fresh tofu yield, tofu protein on dry basis, and tofu hardness, but none of these differences was associated with the origin of the soybean varieties (U.S. vs Japanese).

Tofu as Affected by Physical Properties of Soybeans

Tofu prepared from all soybean varieties tested had a bland taste, smooth texture, and creamy white color. However, tofu made from soybeans with a black hilum (Weber variety) had a less attractive color, with a gray cast over the traditional creamy white.

At complete hydration, the amount of water absorbed by the beans was approximately 1.3 times the original bean weight. Larger beans absorbed more water in proportion to size, but neither the size of the beans nor the amount of water absorbed by the beans was significantly associated with the yield and quality of tofu.

Composition of Tofu as Affected by Soybean Variety

Environmental conditions and seed sources have been known to affect the chemical composition of soybeans (Fehr and Probst 1971, Fehr and Weber 1968). Data obtained from this study using soybeans planted from the same source of seed at the same location

TABLE I
Physical and Chemical Properties of U.S. and Japanese Soybean Varieties

Variety	Color of Seed Coat	Color of Hilum	Moisture (%)	Protein[a] (%)	Oil[a] (%)	Weight (g) of 100 Beans	Weight (g) of 50-g Beans at Complete Hydration
U.S.							
Coles	Tan, dull	Yellow	7.95	43.2	18.5	20.27	114.4
Vinton	Tan, dull	Yellow	8.10	45.1	17.9	24.71	112.1
Weber	Tan	Black	7.71	40.9	19.3	15.24	115.0
Hodgson	Tan	Buff	7.78	40.9	19.4	18.25	112.9
Corsoy	Tan, dull	Yellow	7.86	40.8	18.9	17.74	114.6
Japanese							
Kitamusume	Tan, green hue	Dark brown	7.86	40.8	19.4	22.30	120.2
Tokachi-Nagaha	Tan, green hue	Dark brown	8.05	41.8	17.3	18.65	119.3
Wase-Kogane	Tan, bright	Yellow	8.23	45.2	17.4	17.53	108.8
Yuuzuru	Tan, green hue	Yellow	7.97	42.3	17.7	35.51	123.0
Toyosuzu	Tan, green hue	Yellow	7.94	44.1	18.1	24.45	119.3
SE[b]			0.09	0.5	0.2	0.36	1.1
LSD[c]			0.29	1.6	0.7	1.13	3.6

[a] Dry basis.
[b] Standard error of the mean.
[c] Least significant difference ($P = 0.05$).

TABLE II
Yields and Characteristics of Tofu Prepared from U.S. and Japanese Soybean Varieties

	Soymilk		Fresh Tofu				Dry Tofu			Protein Recovery		
Variety	Protein (%)	Oil (%)	Yield[a] (g)	Moisture (%)	Protein (%)	Oil (%)	Yield[b] (g)	Protein (%)	Oil (%)	In Milk (%)	In Tofu (%)	Hardness (kg)
U.S.												
Coles	3.15	1.49	156.3	84.87	7.56	4.25	54.11	49.92	28.06	67.98	63.07	0.46
Vinton	3.50	1.40	184.1	85.43	7.62	3.79	58.37	52.24	25.98	71.27	67.62	0.37
Weber	3.00	1.71	192.7	85.68	6.80	4.33	59.80	47.52	30.22	68.35	69.52	0.28
Hodgson	3.10	1.63	178.1	84.93	7.35	4.41	58.00	48.75	29.25	71.61	69.11	0.35
Corsoy	3.16	1.62	180.2	85.31	7.15	4.22	55.92	48.63	28.70	71.99	69.80	0.36
Japanese												
Kitamusume	3.07	1.65	167.3	84.37	7.37	4.68	56.59	47.10	29.95	68.25	65.39	0.38
Tokachi-Nagaha	3.09	1.46	175.3	85.12	7.50	3.98	56.71	50.42	26.77	70.49	68.35	0.36
Wase-Kogane	3.41	1.37	169.7	84.20	8.42	4.06	58.43	53.30	25.67	70.29	68.97	0.46
Yuuzuru	3.24	1.41	178.9	85.65	7.16	3.92	55.57	49.83	26.33	71.39	65.48	0.32
Toyosuzu	3.32	1.56	185.8	85.54	7.38	4.30	58.41	51.02	27.23	69.96	67.59	0.32
SE[c]	0.07	0.03	5.8	0.52	0.34	0.17	2.05	0.84	1.35	0.93	2.95	0.02
LSD[d]	0.23	0.08	18.4	1.62	1.07	0.52	6.47	2.65	4.27	2.92	9.28	0.07

[a] From 50 g soybeans (as is basis).
[b] From 100 g soybeans (dry basis).
[c] Standard error of the mean.
[d] Least significant difference ($P = 0.05$).

permit an accurate comparison of varietal differences. Significant varietal differences were noted for protein and oil content of the beans. Also, protein and oil contents of the beans were negatively correlated, whereas moisture and protein were positively correlated. Among the varieties studied, Vinton and Wase-Kogane had the highest protein contents.

Positive correlations ($r = 0.80$) were observed between protein content of the beans and that of the resultant fresh tofu or dry tofu. Similar correlations were also found between oil content of the beans and that of tofu. In making tofu, soybeans are first extracted with water to yield a stable protein and oil emulsion known as soy milk; it is expected that protein and oil contents of the beans directly affect those of the soy milk, which in turn affects the protein and oil contents of the resultant tofu. Because protein and oil contents of the beans are negatively correlated, tofu made from a variety having high protein content would result in tofu having a higher protein–oil ratio than tofu made from a variety with less protein (Table III), the correlation coefficient (r) between soybean protein content and protein–oil ratio being 0.79.

TABLE III
Ratio of Protein to Oil Content of Tofu and Soymilk as Affected by Protein Content of Soybeans

Variety	Protein (%)	Protein/Oil Tofu	Protein/Oil Milk
Wase-Kogane	45.2	2.07	2.49
Vinton	45.1	2.01	2.50
Toyosuzu	44.1	1.87	2.13
Coles	43.2	1.78	2.11
Yuuzuru	42.3	1.89	2.30
Tokachi-Nagaha	41.8	1.88	2.12
Weber	40.9	1.57	1.75
Hodgson	40.9	1.67	1.90
Corsoy	40.8	1.69	1.95
Kitamusume	40.8	1.57	1.86

Yield of Tofu

Tofu prepared from each soybean variety showed no significant difference in yield of dry product but showed significant difference in the yield of fresh tofu (Table II). The difference is, therefore, due to its water content.

No significant correlation was found between the protein content of the soybeans and the yield of tofu. On the other hand, the yield of tofu was found to be positively correlated ($r = 0.67$) to the percentage of protein recovered in processing. Protein recovery does not reflect varietal variation, because significant varietal differences in protein recovery (Table II) were not observed. Furthermore, there was no significant correlation ($r = 0.12$) between protein recovery and protein content of the beans, indicating that the amount of coagulant used in this study was adequate.

Texture of Tofu

Significant variation among soybean varieties was noted in the hardness of resultant tofu. But the hardness of tofu was found to be negatively correlated ($r = -0.65$) to its water content: the hardness of tofu increases as its water content decreases.

Chemical composition of soybeans also has been reported to affect tofu texture. Saio et al (1969) found that gel made from 11S protein isolated from defatted soybean meal was much harder than that made from 7S protein, and they also noted increasing tofu hardness as the amount of phytic acid added to soy milk increased. Because the ratio of 7S to 11S protein and the phytic acid content of the beans may vary among the varieties, Saio and co-workers speculated that soybean variety would have an effect on tofu texture. Smith et al (1960) observed some variations in hardness of tofu made from different varieties of U.S. and Japanese soybeans, but average hardness was nearly the same for the beans from the two sources. Skurray et al (1980) found no significant correlation between the ratio of 7S to 11S protein or phosphorus content and texture of tofu, but they indicated that the texture of tofu was greatly affected by the amount of calcium ion added. A number of other investigators (Saio 1979, Tsai et al 1981, Wang and Hesseltine 1982) also reported that processing conditions greatly affect texture and yield of resultant tofu.

Thus, variations in the ratio of 7S to 11S soybean protein, phytic acid content, and other chemical composition among soyean varieties may affect the texture and yield of tofu, but these variations may not be great enough to have a significant effect, or they may be overcome by other variables. Soybean variety does not seem to play an important role in tofu processing. However, varieties with a dark hilum are not desirable. Also, varieties having high protein content are necessary to produce tofu having high protein content.

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